THE NEW 110-MILLION GALLON PUMP AT THE CHAIN OF ROCKS, ST. LOUIS

By L. A. Day

In order to meet an increased demand for pumping capacity at the low-service pumping station of the city of St. Louis, a contract was awarded for a new turbine-driven centrifugal pump having a maximum capacity of 110,000,000 gallons per twenty-four hours. This will bring the total capacity of this station up to 290,000,000 gallons per twenty-four hours, which will be adequate for some time to come. The new pump will be located in the center pit, there being three pits in all. There are at present two 30,000,000 gallon turbine-driven pumps in this pit. Room was made for the 60-inch suction valve on this pump by channeling off 3 feet of the ledge on the east side of the pit for its entire length north and south. This also provides enough room in the pit for the location of the necessary auxiliaries used in connection with the new pump. The ledge was cut from solid limestone. It was also necessary to tunnel a 60-inch suction line through the limestone for a distance of 40 feet to the suction well which is common to all engines in this station. In addition to the 60-inch suction valve which is located within the pit, stop logs are provided in the wet well for making repairs on the suction valve if needed. The operating floor of the pump pit is 12 feet above the bottom. An automatic push-button electric elevator is used to reach the turbine operating floor from the ground level of the pumping station, which is 45 feet above. The pump will be required to operate under varying heads as the river rises or falls. The average total discharge head will be 60 feet with a minimum of 45 feet and a maximum of 65 feet.

The discharge pipe will be 60 inch diameter and will drop below the floor and then rise vertically, paralleling the west pit wall. The pipe will be enlarged to 72 inches from a flanged Y, which is 60 inches by 72 inches by 42 inches, due to the north 30,000,000 centrifugal pump discharging its water through the same pipe. The new unit will be provided with a 60-inch hydraulically operated discharge valve close to the Y and the old unit with a 42-inch hydraulically operated valve

close up to the 45 degree leg of the Y. The 72-inch line will be extended to the delivery well, which is a common discharge well for all pumps in this station. A 72-inch cast iron Venturi meter tube with a 36-inch throat diameter, the largest cast iron Venturi tube ever built, will be installed just outside of the pumping station.

The pump will deliver from 80,000,000 to 110,000,000 gallons in twenty-four hours against any head varying from 45 to 65 feet. This range of flexibility could not be met entirely with governor adjustment, but will be obtained by opening or closing hand operated valves on the turbine; the speed of the unit thus obtained will be further controlled by an automatic governor. This governor will be of the oil relay type, designed to permit of adjustment while the unit is in operation to any point within the required range of speed, and after being adjusted will maintain the required speed within 2 per cent variation above or below.

The maximum brake horse power of the turbine will be 1550 and the maximum water horse power required, including all pipe friction, will be 1250; the speed of the turbine under these conditions will be 3717 r.p.m. When the pump is delivering 80,000,000 gallons of water in twenty-four hours under a total head of 45 feet the turbine will run at 2946 r.p.m. The pump speed will be lowered by means of reduction gears to 352 r.p.m. when delivering 110,000,000 gallons under 65-feet head, and to 279 r.p.m. when delivering 80,000,000 gallons under a 45-foot head. The guaranteed pump efficiency will be slightly above 80 per cent under all of the specified head and capacity conditions. The suction and discharge openings to the pump will be 48 inches and the 60-inch suction and discharge piping will be gradually reduced near the pumps to this diameter.

The turbine is of the multistage impulse type and will operate with 125 pounds gage pressure and 75° superheat. Provision will be made for bleeding 1500 pounds of steam from one of the low-pressure stages for heating feed water. Bleeding this amount of steam will increase the B.t.u. duty of the unit approximately 3 per cent. The bleeder outlet will be provided with an automatic valve set to carry a pressure of 5 pounds gage on the exhaust line at all times. The dry vacuum pump is of the horizontal crank-and-flywheel type designed to operate at a speed not to exceed 115 r.p.m. The condensate pump will be turbine-driven, connected to a centrifugal pump by means of reduction gears. The circulating pump will be direct connected to the main unit shaft, and will take its water from the 60-inch suction; after passing

through the condenser the water will be discharged back into the main suction pipe. The condenser will be of the water-tube type placed directly under the turbine. Water for circulating purposes only will pass through the condenser, as an excessive amount of friction would have been obtained by passing all of the water pumped by the unit through the condenser, this being the usual water works practice. In order to derive as much heat as possible out of the exhaust steam going to the condenser a primary heater will be placed in the condenser and all the condensate from the condenser will be pumped through this heater before going to the hot well or open feed-water heater. The total condenser surface will be 2825 square feet of seamless drawn brass tubes No. 18 B.W.G., 1 inch in diameter and 12 feet long.

The unit was bought on the bidder's guarantees of duty per million B. t.u. consumed by the unit, including auxiliaries and bled steam, with the provision that the total amount of exhaust steam from the auxiliaries, plus the steam bled from the unit, should not exceed 2200 pounds per hour.

The successful bidder's guarantees were as follows:

	100,000,000 GALLON			80,000,000 GALLON			110,000,000 GALLON		
Head in feet	45	60	65	45	60	65	45	60	65
50° circulating water	113.5	120	122	107	113.75	115	114	120.75	121.5
80° circulating water	106.5	113	115	101.5	108.50	109.5	107	113.50	114.0

The average duty for all of these conditions is 114,562,000 foot-pounds per million B.t.u.'s. which is equivalent to a duty of 134,000,000 foot-pounds per 1000 pounds of steam.

Attention is called to the fact that different duties are obtained with different temperatures of circulating water. This is due to the fact that if the turbine is designed properly, better economies will be obtained with low circulating-water temperatures, owing to an increased vacuum. The average circulating water temperatures for this station throughout the year are 50° for the winter and 80° for the summer. In order to compare bids on this unit the following information was embodied in the specifications:

One million foot pounds of duty will be valued at $2000. That is, if bidder A guarantees 5,000,000 foot pounds higher duty than bidder B, $10,000 will be added to B's bid for comparison with A's bid.

Bidders were instructed to submit curves showing duties guaranteed when pumping 80,000,000, 100,000,000 and 110,000,000 gallons with circulating water temperatures of 50° and 80° and heads of 45, 60 and 65 feet.

During four-fifths of the time each year the pump operates, it is estimated that it will be called on to deliver from 80,000,000 to 110,000,000 gallons under heads varying between 60 and 65 feet. During the remaining one-fifth of the year, it is assumed this pump will deliver from 80,000,000 to 110,000,000 gallons under a 45 foot head. It was further assumed that the unit will deliver 100,000,000 gallons for one half of each year under all head conditions and the remaining half it will deliver either 80,000,000 or 110,000,000 gallons in equal parts.

The process may be represented diagrammatically as follows:

100,000,000 gallons daily

$$\frac{\text{Duty at } 50° + \text{Duty at } 80°}{2} \text{ for 45 ft. head x 1} = \ldots\ldots$$

Ditto for 60 ft. head x 2 = ...
Ditto for 65 ft. head x 2 = ...

$$5) \frac{\text{Sum}}{\text{Duty A}}$$

80,000,000 gallons daily

$$\frac{\text{Duty at } 50° + \text{Duty at } 80°}{2} \text{ for 45 ft. head x 1} = \ldots\ldots$$

Ditto for 60 ft. head x 2 = ...
Ditto for 65 ft. head x 2 = ...

$$5) \frac{\text{Sum}}{\text{Duty B}}$$

110,000,000 gallons daily

$$\frac{\text{Duty at } 50° + \text{Duty at } 80°}{2} \text{ for 45 ft. head x 1} = \ldots\ldots$$

Ditto for 60 ft. head x 2 = ...
Ditto for 65 ft. head x 2 = ...

$$5) \frac{\text{Sum}}{\text{Duty C}}$$

$$\text{Resultant Duty} = \frac{2 \times \text{Duty A} + \text{Duty B} + \text{Duty C}}{4}$$

All of the above conditions must be verified by complete shop tests before the unit is shipped. These shop tests must be on the turbine, gears and pump assembled complete. The shop tests must show duties at least those guaranteed by the contractor and checked by the city's representatives.

After the unit is installed it will be subjected to an endurance test of ten days of twenty-four hours each. A station duty test will then be made as a check on the shop duty test, the station test to be conducted entirely in accordance with recommendations laid down in the latest A.S.M.E code for testing steam driven pumping machinery. The capacity will be measured with a Venturi meter.

The physical data of the unit and auxiliaries is as follows:

Turbine

Make	DeLaval
Brake horse power of turbine	Normal 1300, maximum 1550
Number of stages	13
Number and diameter of rotors	4—27½ in.; 9—24 in.
Revolutions per minute under maximum conditions	3720
Method of speed control	Jahn's governor through oil relay
Percentage of speed obtainable above and below normal by governor regulations	6 above and 15 below
Percentage of speed obtainable above and below normal by hand-regulated nozzle	Approximately 6 above and 20 below
Net weight of turbine without bedplate, pounds	24,000
Diameter and length of bearings, inches	4½ x 14
Diameter of shaft in rotor, inches	10
Diameter of steam admission, inches	6
Diameter of steam exhaust, inches	36

Reduction gear

Net weight of reduction gear complete without bedplate, pound,	32,000
Diameter of driven gear, inches	63.4
Diameter of pinion, inches	6
Width of face of gear in pinion, inches	29¼
Tooth pressure per inch, face of gear and pinion, when pump is delivering 110,000,000 gallon per day at 65 foot head pounds	300
Gear ratio	10.56 to 1
Angle of gear tooth, degrees	45
Mechanical efficiency of gear, per cent	98
Horse power consumed by gear under maximum conditions	31

Pump

Net weight of pump without bedplate, pounds	40,000
Net weight of bedplate for complete unit, pounds	15,000
Diameter of impellers, inches	50
Diameter of shaft at impeller, inches	8
Diameter and length of bearings, inches	One $6\frac{1}{2}$ x 18, one $5\frac{1}{4}$ x 18
Length of shaft between bearings, feet	$8\frac{1}{3}$
Revolutions per minute, maximum	352
Diameter of water suction, inches	48
Diameter of water discharge, inches	48
Efficiency of pump, per cent (for normal conditions)	81

Condenser

Condensing surface, square feet	2825
Diameter of tubes, inches	1
Gage of tubes	No. 18 B. W. G.
Length of tubes, feet	12
Number of steam passes	1
Number of water passes	2
Size of exhaust-steam inlet, inches	36
Net weight of condenser, pounds	20,800
Diameter of condenser shell, feet	5
Length of shell, feet	$14\frac{3}{4}$

Air pump

Revolutions per minute	115
Size of inlet, inches	5
Size of outlet, inches	3
Method of driving air pump	By steam cylinders
Weight of air pump complete, pounds	6400

Condensate pump

Size of pump, inches	$2\frac{1}{2}$
Revolutions per minute	1800
Size of inlet, inches	$2\frac{1}{2}$
Size of outlet, inches	$2\frac{1}{2}$